Elastic Photon Scattering from Excited States of Atoms and Ions

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Abstract–The elastic scattering of photons from excited state configurations of carbon atoms and ions is considered using the S-matrix approach. The method used, exact for fully-filled subshells, averages over magnetic quantum numbers at the amplitude level. Situations where the scattering cross section is much larger or smaller than that for the ground state configuration are identified.

INTRODUCTION

Elastic photon scattering from neutral ground state atoms has been studied extensively (Kane *et al.*, 1986), while scattering from excited states has received little attention. Yet near-resonant Rayleigh scattering has been observed experimentally from excited atoms in plasmas (Rohr, 1969; Wrobel *et al.*, 1976). Here we study the unpolarized cross section for scattering from excited state configurations of carbon atoms and ions for energies above and below the K edge, but above the L edge. Configurations considered involve varying numbers of K and L electrons, with any remaining electrons being placed in an outer (N) shell, and include hollow atom states, where one or more inner shells are completely vacated.

RESULTS

Results for forward angle unpolarized scattering in the energy range 100 eV to 10 keV show that the primary differences between the cross sections are for configurations with different numbers of K electrons. In the high energy limit the forward cross sections all approach the form factor value, being proportional to the square of the total number of electrons. All neutral configurations with six electrons therefore have a common high energy limit for the forward cross section. Moving down in energy towards the K edge the cross sections separate according to the number of K electrons, giving rise to three groupings, with the larger cross sections being associated with more K electrons. This reflects the influence of the K anomalous amplitudes.

In the region below the K resonances (but above the L edge) the situation is more complex. Again there is a overall separation of cross sections according to the number of K electrons, as the K electrons are no longer contributing to scattering in this region. But in this case it is the configurations with fewer K electrons that now have the larger cross sections. For a given number of K electrons, having more electrons in the $L2/L3$ subshells tends to enhance the cross section, reflecting the influence of the strong $L2/L3$ to K dipole allowed resonance. A cross section may or may not exhibit a deep minima just below this resonance as a result of interference between the real subshell amplitudes. If however the configuration is such that there is a net downward number of these transitions such a minima does not appear, and the cross section is much larger than the ground state result, which does have such a minimum.

The usual numerical method of summing over magnetic quantum numbers at the level of the scattering amplitude, giving rise to spherically symmetric wavefunctions which are weighted by the number of electrons which are present, is exact for fully-filled subshells, but not for partially-filled shells. We have investigated the corrections obtained by treating the dominant electric dipole amplitude for the partially-filled inner shells exactly, and found them to be small in most of the studied energy range. This is due to the large contribution to the amplitude from the remaining fully-filled subshells. One situation in which the corrections are important is in regions where the averaged-amplitude approach can give a near-zero minimum in the cross section, such as just below the resonance region, where these corrections can even dominate the cross section. For the case of ionic excited states, where there are only a few electrons, all in partially-filled subshells, these considerations will also be more important.

CONCLUSIONS

The main differences between cross sections in a given energy regime depend on the number of electrons associated with any edges in that regime (here the K electrons) and also on the number of electrons in subshells associated with strong resonant transitions in that regime [here the K and $L2/L3$ (sub)shells]. Large differences from the ground state result can occur, particularly just below the K resonance region where the ground state cross section passes though a deep minimum, or for large angle scattering above the K threshold where excited state cross sections can be much smaller.

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